LIFE HISTORY, BIOLOGY, HOST PLANTS AND NATURAL ENEMIES OF THE LILLY PILLY PSYLLID, *TRIOZA EUGENIAE* FROGGATT (HEMIPTERA: TRIOZIDAE)

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Abstract

The lilly pilly psyllid, *Trioza eugeniae* Froggatt, attacks the flush growth of the magenta lilly pilly, *Syzygium paniculatum*. The nymphs form pit galls on expanding leaves, distorting and stunting plant growth. Rearing experiments showed that the psyllid was able to complete its life history on 7 species of trees belonging to 3 allied genera in the Myrtaceae: *Acmena*, *Syzygium* and *Waterhousea*. Birds, spiders, coccinellids, ants and a tettigoniid were recorded as predators of *T. eugeniae* eggs, nymphs and adults. The most important natural enemy was the eulophid parasitoid *Tamarixia* sp.

Introduction

The lilly pilly psyllid, *Trioza eugeniae* Froggatt, is native to eastern Australia and is a serious pest of young trees of magenta lilly pilly, *Syzygium paniculatum* (e.g. Morgan 1984, McMaugh 1985, Downer *et al.* 1991, Mead 1994, Dahlsten *et al.* 1995). *S. paniculatum* is native to four patches of littoral rain forest on the NSW coast (Floyd 1989) and has become a popular ornamental tree in South Australia, Victoria, New South Wales and Queensland (GRY unpublished data). It is also planted in the USA where it is used in topiary (Mead 1994, Dahlsten *et al.* 1995). The recent introduction of *T. eugeniae* to the USA has resulted in severe damage to ornamental *S. paniculatum* (Downer *et al.* 1991, Mead 1994).

Females oviposit along the margins of newly opened leaves of the flush growth. First instar nymphs hatch and crawl to the undersides of the expanding young leaves, where they settle. Subsequent instars develop in cup-shaped pit galls (Morgan 1984, Downer *et al.* 1991, Luft and Paine 1997b). At high densities nymphs also form galls on the upper sides of leaves, developing fruit, shoots and young branchlets (Downer *et al.* 1991, Dahlsten *et al.* 1995, GRY unpublished data). The gall grows with each instar and at the end of the fifth instar the adult emerges through a slit in the dorsal exoskeleton (Morgan 1984, Downer *et al.* 1991). Galling of flush results in distorted and stunted growth, both in nursery stock and recently planted young trees (GRY unpublished data). Additionally, the nymphs produce a dry, powdery honeydew which covers the leaves of the plants and, along with galling, reduces the aesthetic quality of ornamental plants (Luft and Paine 1997a).

When discussing the host range of psyllids, Hodkinson (1974) defined a host plant as a species on which a psyllid could complete its life history. Psyllid nymphs generally only feed on one or several closely related host species (Taylor and Carver 1991). Froggatt (1901) described *T. eugeniae* from

Eugenia smithii (Myrtaceae), now known as *Acmena smithii*. The names *E. smithii* and *Syzygium smithii* were, until recently, often used incorrectly in the Australian nursery trade for *S. paniculatum* (GRY unpublished data), so it is possible that Froggatt's record was from *S. paniculatum*. Morgan (1984), Mead (1004) and Luft and Paine (1998) all stated that *T. eugeniae* had a narrow host range and probably was confined to *S. paniculatum*. However, *Acmena*, *Syzygium* and *Waterhousea* are allied genera of trees in the family Myrtaceae found in rainforests extending from southeastern to northeastern Australia, with some species also found in the monsoon forest and savanna woodland of the Northern Territory (Hyland 1983, Floyd 1989). Many species belonging to these three genera show insect damage similar to that caused by *T. eugeniae* on *S, paniculatum* (GRY unpublished data).

Little has been published on the natural enemies of *T. eugeniae* (Dahlsten *et al.* 1995), the exception being the nymphal parasitoid *Tamarixia* sp. (Hymenoptera: Eulophidae), which was introduced from Australia into California for the biological control of the psyllid (Mead 1994, Dahlsten *et al.* 1995, Luft and Paine 1998).

This paper describes observations on the biology, life history, host range and natural enemies of *T. eugeniae*, which either differ from published data or had not been recorded previously.

Material and methods

Adult *T. eugeniae* were collected from a single tree of *S. paniculatum* growing in a backyard at Ryde, NSW. A stock culture of *T. eugeniae* was established on cuttings raised from the same tree. The cuttings were struck in quartz gravel and transplanted into 200 mm diameter pots. Host plants were fed weekly with Aquasol® at a concentration equivalent to 100 ppm of nitrogen. Pots, each containing 2 host plants, were placed in 450 x 450 x 450 mm aluminium framed cages enclosed with 0.6 mm polyamide gauze. The cages were placed in a glasshouse where the daily temperature ranged from 18-26°C. Observations were made on the life history and behaviour of *T. eugeniae* both in the cages and in the field. Measurements of life stages were made under a stereomicroscope using an eye-piece micrometer.

To test the host range of *T. eugeniae*, cuttings were taken from 13 species of trees at the Ryde School of Agriculture, belonging to the genera *Acmena*, *Syzygium* and *Waterhousea* (Table 1). The cuttings were raised in pots as described above and each pot was placed in a cage with 2 female and 5 male *T. eugeniae*. Adults were removed from the cages 48 hours after the start of oviposition. The cages were kept under observation until either *T. eugeniae* completed two generations or all the life stages died. A generation was defined as from one egg stage to the next. Field observations were made on the same species of *Acmena*, *Syzygium* and *Waterhousea* (Table 1) at the Ryde School of Horticulture and the Royal Botanic Gardens, Sydney.

Table 1. Survival of *Trioza eugeniae* on different host plants in cages and in the field.

Host species	Generations completed in cages	Remarks
Syzygium australe	2	Adults, eggs and nymphs in the field
Syzygium francisii	<1	Adults fed, oviposition, infested leaves shed at instars 2 and 3. No nymphs in pit galls in the field
Syzygium hodgkinsoniae	0	Adults fed, no oviposition
Syzygium luehmannii	1	Adults fed, oviposition, most infested leaves shed at instars 2 and 3. No nymphs in pit galls in the field
Syzygium moorei	2	Adults, eggs and nymphs in the field
Syzygium oleosum	2	Adults, eggs and nymphs in the field
Syzygium paniculatum	2	Adults, eggs and nymphs in the field
Syzygium wilsonii ssp. *wilsonii*	<1	Adults fed, oviposition, infested leaves shed at instars 3 to 5. Nymphs in pit galls in the field
Acmena hemilampra	0	Adults fed, oviposition, nymphs did not develop beyond instar 2
Acmena ingens	2	Adults, eggs and nymphs in the field
Acmena smithii type	0	Adults fed, oviposition, nymphs did not develop beyond instar 2
Acmena smithii rheophytic race	0	Adults fed, no oviposition
Waterhousea floribunda	2	Adults, eggs and nymphs in the field

To measure the fecundity of *T. eugeniae*, 15 cages were set up, each containing a potted *Syzygium oleosum* with one newly emerged female and 3 male *T. eugeniae*. The potted host plants were removed each day and counts made of the number of eggs laid. Plants with eggs were retained to determine percentage egg hatch and replaced in the cages with fresh plants.

Observations were made on the natural enemies of *T. eugeniae* both in cages and in the field. To determine the incidence of the parasitoid *Tamarixia* sp. in different life stages of *T. eugeniae*, a total of 25 shoots were sampled each week from young *S. paniculatum* and *S. oleosum* trees. Counts were made of each nymphal stage and parasitised nymphs were cut from leaves and held in glass vials for parasite emergence. To determine the development period for the parasitoid, 4 field collected females were caged with 30 newly moulted fourth instar nymphs of *T. eugeniae*.

Results

Body length for adult *T. eugeniae*, from the tip of the head to the tip of the abdomen, was 1.6 mm ± 0.03 (range 1.4-1.8 mm, n = 13) for males and 1.8 mm ± 0.04 (range 1.7-1.9 mm, n = 12) for females. Body length from the tip of the head to the tip of the folded wings was 2.8 mm ± 0.04 (range 2.5-3.0 mm, n = 13) for males and 3.05 mm ± 0.04 (range 2.7-3.2 mm, n = 12) for females. Both sexes had a white wax-like covering on both the first and pregenital abdominal tergites. Recently emerged adults fed around the margins of the pits from which they emerged, as well as on the reverse side of the pit, before dispersing. When feeding, adults continually moved their raised abdomens from side to side through an angle of 20°. In periods between oviposition on expanding leaves, females descended to flush branchlets to feed.

Eggs were yellow in colour and fusiform, more tapered at one end than the other, with the blunt end inserted into the margin of the expanding leaf. Eggs were a mean of 0.34 mm ± 0.003 (range 0.27-0.36 mm) in length and 0.1 mm ± 0.007 (range 0.09-0.13 mm) at the widest point (n = 34). Hatching occurred between 0600 and 0800 h and the first instar nymphs remained motile for up to 7 hours before settling on the underside of the leaf. First instar nymphs were flattened dorsally and convex ventrally, a body length of 0.36 mm ± 0.004 (range 0.33-0.38 mm) in length and a width of 0.17 mm ± 0.007 (range 0.13-0.18 mm) across the mesothorax (n = 25). The dorsal sclerites of the head, thorax and abdomen were confluent, forming a dorsal shield with the legs and antennae protruding beyond the margin of the shield. After moulting to second instar a shallow pit began to develop beneath the nymph. The dorsal shield became larger, relative to the rest of the nymph, and a narrow wax-like fringe developed around the margin of the shield. The wax-like fringe was found in succeeding instars and appeared to seal the nymph in the pit. Pits became deeper and wider with each instar. Once the leaf was fully expanded instars 2 to 4 did not undergo further moults and subsequently died. When third, fourth or fifth instars were dislodged from their pits the nymphs were motile, but unable to settle on the leaf or re-establish in empty pits. Dislodged nymphs eventually died of desiccation.

In the field, instars 1 and 2 were the most susceptible to desiccation. From 2-8 January 1994 maximum temperatures were between 33 and 39°C, resulting in 100% mortality of instars 1 and 2, while some later instars survived.

Trioza eugeniae was able to complete two generations on caged *Syzygium australe, S. moorei, S. oleosum, S. paniculatum, Acmena ingens* and *Waterhousea floribunda*. Additionally, all life stages were found on these hosts in the field. *T. eugeniae* was able to complete one generation on caged *S, luehmannii*; however most infested leaves were shed when the nymphs reached instars 2 and 3. Empty pit galls were found on *S. luehmannii* and *S. francisii* in the field. Adults fed and oviposited on caged *S. francisii* and

S. wilsonii ssp. *wilsonii* but infested leaves were shed before the nymphs reached instar 5. Pit galls containing nymphs were found on leaves of *S. wilsonii* ssp. *wilsonii* in the field. *T. eugeniae* fed and oviposited on caged *A. hemilampra* and *A. smithii* type but the nymphs did not develop beyond instar 2. No pit galls were found on either of these plants in the field. On caged *S. hodgkinsoniae* and *A. smithii* rheophytic race adults fed without ovipositing and no *T. eugeniae* life stages were found on these hosts in the field.

Females mated within 24 h of introduction to the cages containing potted *S. oleosum* and ovipostion began up to 48 h after mating. Of the 15 females, 2 died without laying eggs. The remaining 13 females lived for a mean of 11 days (range 4-18 days) and continued to mate throughout their lives. Females laid a mean of 18 eggs per day (range 6.4-35.5). Over their entire lifetime, females laid a mean of 198 eggs (range 109-331). There was no statistical relationship between longevity and the number of eggs laid, $r = 0.01$, but larger females laid more eggs than smaller ones. Egg hatch per female was 89% (range 72-100%). Eggs hatched in a mean of 4 days (range 3-7 days, $n = 2,579$).

Birds observed feeding on *T. eugeniae* were the noisy miner, *Manorina melanocephalus* (Latham) and the red wattle bird, *Anthochaera carunculata* (White). Invertebrate predators of *T. eugeniae* nymphs were: larvae and adults of the coccinellids *Cryptolaemus montrouzieri* Mulsant, *Halmus chalybeus* (Boisduval) and *Harmonia conformis* (Boisduval) (Coleoptera); larvae of an unidentified syrphid (Diptera); the tramp ants *Pheidole megacephala* (Fabricius) and *Technomyrmex albipes* (F.Smith), and the native ant *Iridomyrmex* sp. (Hymenoptera). Second and third instar nymphs of *Conocephalus semivittatus* (Walker) (Orthoptera: Tettigoniidae) were observed feeding on *T. eugeniae* eggs. The spiders *Oxyopes* sp. (Oxyopidae) and a species of Salticidae were observed attacking newly emerged *T. eugeniae* adults.

The nymphal parasitoid *Tamarixia* sp. (Hymenoptera: Eulophidae) was the only parasitoid found attacking *T. eugeniae*. Parasitised nymphs from instars 2-5 were recovered from the field and emergence holes were recorded from the cadavers of instars 3, 4 and 5. Percent parasitism of field populations of *T. eugeniae* ranged up to 3, 22, 62 and 47% for instars 2, 3, 4 and 5 respectively. Development time for *Tamarixia* sp. from oviposition to adult emergence was a mean of 17 days (range 16-19 days, $n = 26$).

Discussion

The wax-like covering on the dorsal abdominal sclerites combined with the side-to-side movements of adults when feeding are possibly strategies to confuse predators. Recently emerged adults fed around vacated pit galls suggesting that, for a short period, this tissue may be nutritionally superior to non-galled parts of shoots and leaves. Hodkinson (1984) maintained that gall formation produced a nutrient sink, which offered a higher quality of soluble

nutrients than the surrounding mature leaf tissue. At the time of adult emergence the leaf tissue was becoming mature with a corresponding decline in the levels of soluble nutrients available to the psyllid, so feeding around the empty pit may have given young adults a nutritional boost before dispersing to feed on flush growth.

The dorsal shield with the surrounding wax-like fringe in instars 2-5 appears to seal nymphs in the pit galls, thereby preventing desiccation. This observation agrees with Hodkinson (1974), who stated that nymphal stages of psyllids exhibited morphological and behavioural adaptations to resist desiccation.

The inability of nymphs from instars 2-5 to develop on expanded leaves indicates that *T. eugeniae* is dependent on flush growth to complete its development. Since seedlings and young trees have a higher proportion of flush growth than mature trees, these stages are more attractive to the psyllid and consequently suffer more damage.

Trioza eugeniae was able to survive and reproduce on six species of tree in three different genera. *Syzygium luelmannii, S. francisii* and *A. wilsonii* ssp. *wilsonii* appeared able to support populations of *T. eugeniae*, although nymphal mortality was high. There are 7, 52 and 4 species of *Acmena, Syzygium* and *Waterhousea* respectively recorded from Australia (Hyland 1983). Since *T. eugeniae* has been recorded from Adelaide in South Australia to Atherton in northern Queensland, the host range of the psyllid is probably more extensive than the current study indicates (Morgan 1874, Dahlsten *et al.* 1995, GRY unpublished data). The wide host range of *T. eugeniae* is unusual as most species of psyllids are specific to one or two closely related species of host plant (Hodkinson 1984, Taylor and Carver 1991). For example, a closely related *Trioza* sp. from the Northern Territory has only been recorded from *Syzygium suborbiculare* (GRY unpublished data, G. Taylor pers. comm.).

The mean fecundity of 198 eggs per female was higher than the 152 eggs recorded by Downer *et al.* (1991). The difference probably can be explained by the high concentration of nitrogen fed to the host plants and the regular provision of fresh hosts. Downer *et al.* (1991) noted that the number of eggs laid was dependent on the availability of oviposition sites. Luft and Paine (1997b) and Luft *et al.* 2001a, 2001b) found that *T. eugeniae* females preferred to oviposit on the margins of unexpanded leaves and, if females encounter a fully occupied margin, they will oviposit on another suitable leaf if available.

Trioza eugeniae has a wide variety of vertebrate and invertebrate predators but their effect on the psyllid populations is unknown. The tettigoniid *Conocephalus semivittatus* is a commonly recorded predator of hemipteran eggs (Rentz 1996, GRY unpublished data).

The only parasitoid recovered was *Tamarixia* sp. Fourth and fifth instar *T. eugeniae* nymphs were the preferred hosts with parasitism of 62 and 47% respectively. This indicates that *Tamarixia* sp. probably controls *T. eugeniae* populations. The results differ slightly from those of Dahlsten *et al.* (1995), who found that third and fourth instar nymphs were the preferred hosts, while the development time for *Tamarixia* sp. was 14 days compared with the 17 days of the current study.

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